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Canadian Journal of Earth Sciences

Réimpression du

Journal canadien de sciences de la terre

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Volume 28 • Number 2 • 1991

Pages 209–224

Printed in Canada / Imprimé au Canada

93-01447/

Geochronological evidence for multiple tectono-thermal overprinting events in the East Kemptville muscovite–topaz leucogranite, Yarmouth County, Nova Scotia, Canada

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Received March 12, 1990
Revision accepted October 5, 1990

The East Kemptville muscovite–topaz leucogranite, located in Yarmouth County, Nova Scotia, Canada, is host rock to the only producing primary tin deposit in North America (56 Mt, 0.165% Sn). Previous geochronological studies include (*i*) Rb–Sr whole-rock analyses of the quartz–topaz greisens, which indicated a date of 337 ± 5 Ma, and (*ii*) $^{40}Ar/^{39}Ar$ analyses of greisen muscovite, which indicated apparent plateau dates of ca. 300 Ma. However, the pervasive development of deformational fabrics at East Kemptville suggests that both the Rb–Sr whole-rock and $^{40}Ar/^{39}Ar$ muscovite ages are at best minimum estimates for the inferred time of mineralization. In the present study, Rb–Sr whole-rock and mineral (muscovite, plagioclase, K-feldspar) analyses and $^{40}Ar/^{39}Ar$ incremental-step heating of a muscovite separate indicate the following: (*i*) diffusion of Sr on the whole-rock scale terminated at 344 ± 5 Ma (11 point isochron date), coincident with closure of muscovite to intracrystalline diffusion of Ar (apparent plateau date of 338 ± 2 Ma) and (*ii*) internal reequilibration of Sr among muscovite, feldspar, and whole rock varied considerably such that Rb–Sr whole rock – muscovite pairs give dates of 361–311 Ma (mean = 330 Ma, n = 7), whereas whole rock – plagioclase – K-feldspar give dates of 276–240 Ma (mean = 254 Ma, n = 7). This younger thermal event is reflected in apparent dates of 269–286 Ma for the low-temperature steps of the $^{40}Ar/^{39}Ar$ muscovite age spectrum.

Collectively the data indicate that the East Kemptville area either cooled slowly over a protracted period of time (ca. 100 Ma) or experienced episodic tectono-thermal activity at ca. 344, 330, and 254 Ma. Examination of previously published geochronological data for the southern Meguma Terrane indicates that these aforementioned ages broadly coincide with earlier documented magmatic or tectono-thermal events (e.g., intrusion of Wedgeport Pluton at 315 Ma). Inferences by some workers of mid-Carboniferous magmatism in the Meguma Terrane are, however, not supported by the present study.

Le seul gîte primaire qui produit de l'étain (56 Mt, 0,165%) en Amérique du Nord, localisé au comté de Yarmouth, en Nouvelle-Écosse, au Canada, se trouve dans le massif de leucogranite à muscovite–topaze de Kemptville Est. Les données géochronologiques déjà publiées pour cette région provenaient (*i*) de datations Rb–Sr sur roche totale de greisens à quartz–topaze qui fournissaient une date de 337 ± 5 Ma, et (*ii*) des analyses $^{40}Ar/^{39}Ar$ sur la muscovite du greisen qui donnaient des âges plateaux autour de 300 Ma. Cependant, les fabriques de déformation développées en profondeur à Kemptville Est suggèrent que le chronomètre Rb–Sr sur roche totale et les âges $^{40}Ar/^{39}Ar$ sur la muscovite correspondent, tout au plus, à des estimations de l'âge minimum de l'épisode de minéralisation. Dans la présente étude, les analyses Rb–Sr sur roche totale et minéraux (muscovite, plagioclase, feldspath-K), ainsi que les âges $^{40}Ar/^{39}Ar$ par chauffage incrémentiel sur un concentré de muscovite mettent en évidence les phénomènes suivants : (*i*) une diffusion du Sr à l'échelle de la roche totale, terminée il y a 344 ± 5 Ma (11 points sur l'isochrone), et dont la fin coïncidait avec la fermeture de la muscovite et diffusion intracristalline de l'Ar (âge plateau apparent de 338 ± 2 Ma) et (*ii*) la rééquilibration interne du Sr parmi la muscovite, le feldspath et la roche totale a varié suffisamment pour que le couple roche totale – muscovite fournisse des âges qui oscillent entre 361 et 311 Ma (moyenne = 330 Ma, n = 7), alors que le triplet roche totale – plagioclase – feldspath potassique donne des âges qui varient de 276 à 240 Ma (moyenne = 254, n = 7). L'événement thermique le plus récent se situe à l'intérieur des dates apparentes de 269–286 Ma, correspondant aux paliers des basses températures du spectre de $^{40}Ar/^{39}Ar$ dans la muscovite.

Toutes ces données obtenues à Kemptville Est peuvent être interprétées de deux façons, soit que la région ait connu un refroidissement lent durant une longue période de temps (approx. 100 Ma), ou qu'elle ait subi à trois reprises une activité tectono-thermique, il y a environ 344, 330 et 254 Ma, respectivement. L'examen des données géochronologiques déjà publiées pour la partie sud du terrane de Meguma indique que nos âges, mentionnés ci-dessus, coïncident largement à des événements magmatiques ou tectono-thermiques décrits antérieurement (ex. intrusion du pluton de Wedgeport à 315 Ma). Cependant la présente étude ne contribue pas à étayer les hypothèses formulées antérieurement par les auteurs qui invoquaient un magmatisme au Carbonifère moyen dans le terrane de Meguma.

[Traduit par la rédaction]

Can. J. Earth Sci. 28, 209–224 (1991)

Introduction

The East Kemptville tin deposit (56 Mt, 0.165% Sn (Moyle 1985); 1988 production of 3700 t), located in Yarmouth County, southwestern Nova Scotia, Canada (Fig. 1), currently represents the only primary tin producer in North America. The presence of the East Kemptville deposit and other lithophile-element mineralized centres in the Canadian Appalachians (Fig. 1) has prompted comparisons with the European Hercynian granitoid provinces hosting Sn, W, Mo, Sb, and U mineralization, particularly the lithophile metalliferous provinces of Cornwall, Britanny, the Massif Central, and Iberia (Strong 1980). Fundamental in such comparisons and in documenting metallogenic provinces within local regions (e.g., Chatterjee 1983) are the ages of the host rock and the mineralizing event. For example, the Central Andean tin belt is characterized by two distinct mineralizing episodes of Triassic

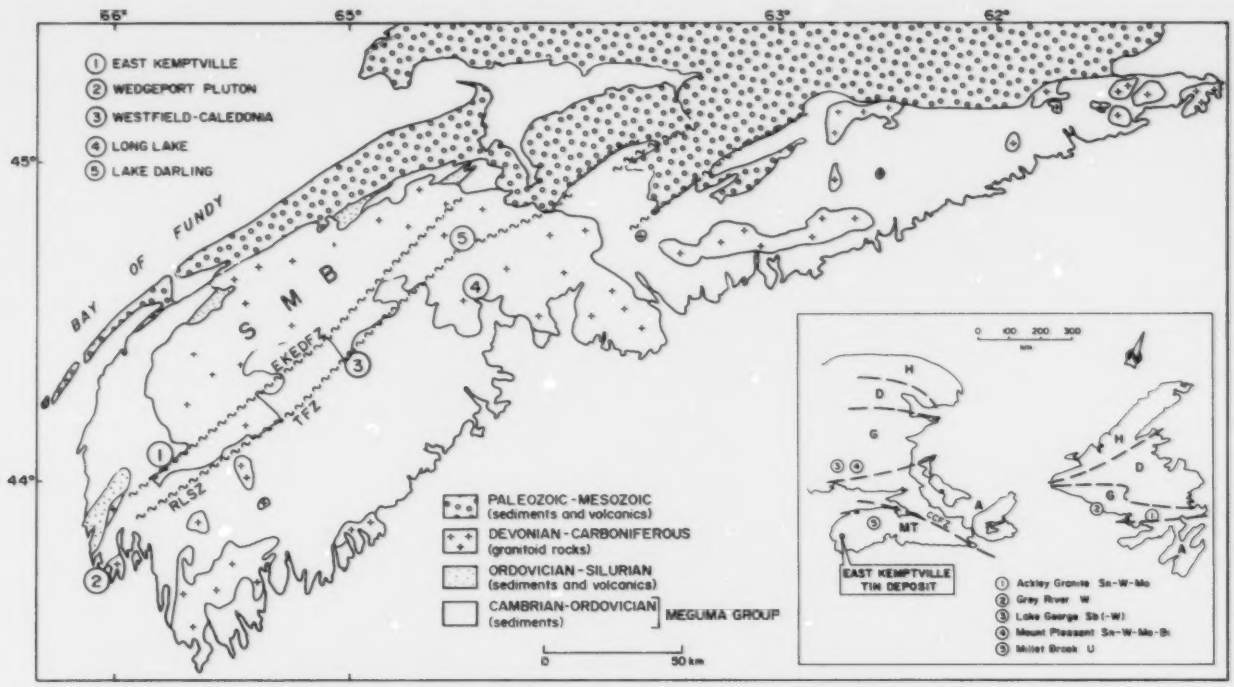


FIG. 1. Simplified geology of the Meguma Terrane showing (*i*) the location of the East Kemptville tin deposit; (*ii*) trace of the East Kemptville – East Dalhousie fault zone (EKEDFZ), Rushmere Lake shear zone (RLSZ), and Tobiatic fault zone (TFZ) (Giles 1985; Smith 1985; Kontak 1987*a*; O'Reilly 1988; R. J. Horne, personal communication, 1989); and (*iii*) locations of the Wedgeport Pluton, and the Long Lake, Lake Darling, and Westfield–Caledonia areas discussed in the text. SMB, South Mountain Batholith. Inset map shows the outlines of the major terranes in the Canadian Appalachians (after Williams and Hatcher 1983) and some important occurrences of Sn , W, U, Mo, Bi, and Sb mineralization. The trace of the Cobequid–Chedabucto fault zone (CCFZ), boundary between the Avalon and Meguma terranes is also shown. A, Avalon; MT, Meguma Terrane; G, Gander; D, Dunnage; H, Humber.

and Miocene–Pliocene age (Grant *et al.* 1979; McBride *et al.* 1983; Clark *et al.* 1984; Kontak *et al.* 1987), whereas the Cornish tin field is, broadly speaking, represented by a single, protracted mineralizing event of some 30 Ma duration (Bray and Spooner 1983; Jackson *et al.* 1982; Darbyshire and Shepherd 1985). Hence, obtaining absolute ages for both the host rock and mineralization has important ramifications with respect to both the academic and the exploration efforts directed toward metallogenic provinces.

The East Kemptville tin deposit, hosted by a topaz–muscovite leucogranite, has been the focus of previous geochronological investigations by Zentilli and Reynolds (1985) and Richardson *et al.* (1988) using the $^{40}Ar/^{39}Ar$ and whole-rock Rb–Sr techniques, respectively (Fig. 2). Zentilli and Reynolds (1985) interpreted two of the three muscovite age spectra produced as indicating that mineralization occurred at ca. 300 Ma, although the high temperature steps (~61% of the gas released) of one sample indicated an apparent plateau date of ca. 350 Ma. The significance of this latter sample was not discussed in detail, other than noting that it lay just outside the zone of maximum mineralization. In contrast, Richardson *et al.* (1988) interpreted the 337 ± 5 Ma Rb–Sr whole-rock isochron date for greisen samples as reflecting the time of mineralization. A 317 ± 5 Ma conventional K–Ar date on greisen muscovite intergrown with cassiterite mineralization was also obtained for material from East Kemptville by D. J. Kontak (unpublished data) in 1982 using the K–Ar facilities at Queen's University, Kingston, Ontario. This date is slightly older than the integrated ages of two of the muscovites analyzed by Zentilli and Reynolds (1985).

As a consequence of detailed mapping of the East Kemptville area, Kontak *et al.* (1986) and Kontak (1987*a*, 1987*b*) documented the presence of previously unrecognized deformational fabrics within the leucogranite, greisens, and veins (see below). Because of the deformational structures in the deposit area, the discordance of one of the $^{40}Ar/^{39}Ar$ age spectra reported by Zentilli and Reynolds (1985), and discordant $^{40}Ar/^{39}Ar$ age spectra for samples from around the East Kemptville area (see below; Reynolds *et al.* 1981), Kontak (1987*a*) questioned the validity of the 300 Ma age assigned to the mineralization. Following similar reasoning, Kontak (1990) doubted the interpretation of Richardson *et al.* (1988) that the 337 Ma Rb–Sr whole-rock isochron date represented the time of mineralization.

Keeping in mind the susceptibility of both Rb–Sr and K–Ar isotopic systems to disturbance, and hence resetting due to overprinting by tectono-thermal events (e.g., Hart 1964; Cormier 1969; Berger 1975; Dallmeyer 1975; Bell and Blenkinsop 1978; Jager 1979; Harrison and McDougall 1980; Evans 1989), a detailed geochronological investigation of the East Kemptville leucogranite was undertaken to resolve the apparent discrepancies among the previous studies and elucidate the chronology of magmatic, hydrothermal, and tectono-thermal events. In this paper we present additional Rb–Sr and $^{40}Ar/^{39}Ar$ data for the East Kemptville leucogranite in an attempt to resolve the chronological evolution of the

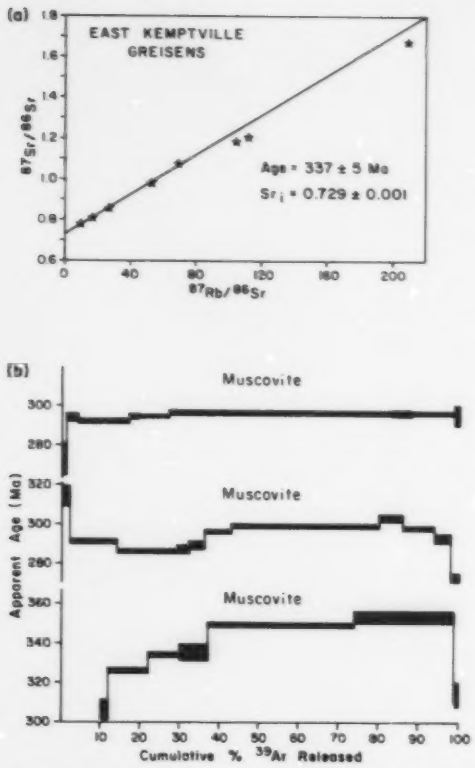


FIG. 2. Results of previous geochronological dating at East Kemptville. (*a*) Rb–Sr isochron plot of whole-rock greisen samples (after Richardson *et al.* 1988); (*b*) $^{40}Ar/^{39}Ar$ age spectra for muscovite from greisen and granite (Zentilli and Reynolds 1985). See inset in Fig. 3 for sample locations. Note that for the oldest sample the high-temperature gas fractions (~61%) indicate an apparent age of ca. 350 Ma.

area. In addition, the results are discussed in terms of the metallogeny of the South Mountain Batholith and the tectono-thermal evolution of the southwest Meguma Terrane.

Regional geological setting

The East Kemptville area is located within the southern part of the Meguma Terrane, the easternmost terrane of the Appalachian collage (Williams and Hatcher 1983) (Fig. 1). The Meguma Terrane was emplaced during the Acadian orogeny, which culminated in Middle to Late Devonian time (Muecke *et al.* 1988). However, continued transpression of the Meguma Terrane after initial collision and emplacement is documented by the presence of superimposed deformation zones throughout the Meguma Terrane and onlapping sequences (e.g., Keppie 1982; Mawer and White 1987; Mawer and Williams 1986; Keppie and Dallmeyer 1987; Ryan *et al.* 1987; Waldron *et al.* 1989). $^{40}Ar/^{39}Ar$ dating of whole-rock phyllite, amphibole, and mica throughout the Meguma Terrane indicates that a series of tectono-thermal events occurred, commencing with regional metamorphism at ca. 400 ± 10 Ma (Reynolds and Muecke 1978; Keppie and Dallmeyer 1987; Muecke *et al.* 1988) and continuing episodically until ca. 220–230 Ma. The latter time is represented by $^{40}Ar/^{39}Ar$ dates obtained for K-feldspar samples from granites (Reynolds *et al.* 1987) and probably reflects tectono-thermal activity associated with the initial rifting that generated the Atlantic Ocean.

The Meguma Terrane is dominated by two lithologic units, namely the lower Paleozoic Meguma Group and the peraluminous South Mountain Batholith (Fig. 1). The former consists of the lower, sandstone-dominated Goldenville Formation and overlying, shale-dominated Halifax Formation. Both were penetratively deformed and folded into northeast-trending, shallow-plunging structures during the Acadian orogeny (Keppie 1979). The South Mountain Batholith, a composite intrusion with granodiorite through to late-stage leucogranite differentiates (MacDonald *et al.* 1989), was intruded ca. 370 Ma ago (Clark and Halliday 1980; Reynolds *et al.* 1981, 1987), thus postdating the regional deformational event that affected Meguma Group rocks. However, major zones of deformation transect the South Mountain Batholith (Figs. 1, 3) (Horne *et al.* 1988; R. J. Horne, personal communication, 1990), one of which is continuous through the East Kemptville area and is appropriately referred to as the East Kemptville – East Dalhousie fault zone (Kontak 1987*a*; O'Reilly 1988; R. J. Horne, personal communication, 1990). Structures of similar orientation (i.e., northeast to east trending and subvertical) also overprint earlier regional fabrics within the Meguma Group (e.g., Shelburne area: Hwang and Williams 1988) and Late Devonian – Early Carboniferous granitoids along the Cobequid–Chedabucto fault system (Fig. 1) (Mawer and White 1986; Mawer and Williams 1986; Pe-Piper and Turner 1988; Waldron *et al.* 1989).

Recently, Giles (1985) suggested the presence of a major transcurrent fault within the Meguma Terrane, which he named the Tobiatic fault zone (Fig. 1). Although the configuration of this structure has been reinterpreted following subsequent field studies (MacDonald *et al.* 1989; R. J. Horne, personal communication, 1989), its significance has not diminished. Of particular relevance is the extension of the fault from within the South Mountain Batholith into the overlying Carboniferous basins, which is evidence of post-Viséan movement (Giles 1985; Giles and Chatterjee 1988).

Geological setting of the East Kemptville leucogranite within the southwestern termination of the South Mountain Batholith

The geology of the southwestern termination of the South Mountain Batholith is presented in Fig. 3. This region is informally referred to as the Davis Lake pluton (MacDonald *et al.* 1989; cf. Richardson 1988*a*, 1988*b* and Richardson *et al.* 1989). The pluton has a subcircular outline and is composed predominantly of a coarse-grained biotite–muscovite leucomonzogranite; more mafic phases (e.g., biotite granodiorite, biotite monzogranite) account for volumetrically minor amounts of the pluton. The prominent northeast trend and elongate extension of the southwestern most part of the Davis Lake pluton suggest that a preexisting structure may have, in part, controlled the shape of the intrusion (R. J. Horne, personal communication, 1989). In addition, we emphasize the presence of two subparallel, northeasterly trending shear zones informally referred to as the East Kemptville shear zone (Kontak 1987*a*, 1987*b*; O'Reilly 1988) and the Rushmere Lake shear zone (Smith 1985). The degree of deformation within these zones varies greatly, and as stated previously, they extend for a considerable distance to the northeast as the East Kemptville – East Dalhousie fault zone and the Tobeatic fault zone, respectively (Fig. 1). A fine-grained leucomonzogranite phase, which has a pronounced elliptical shape with a northeasterly trend (Fig. 3), represents a structurally modified

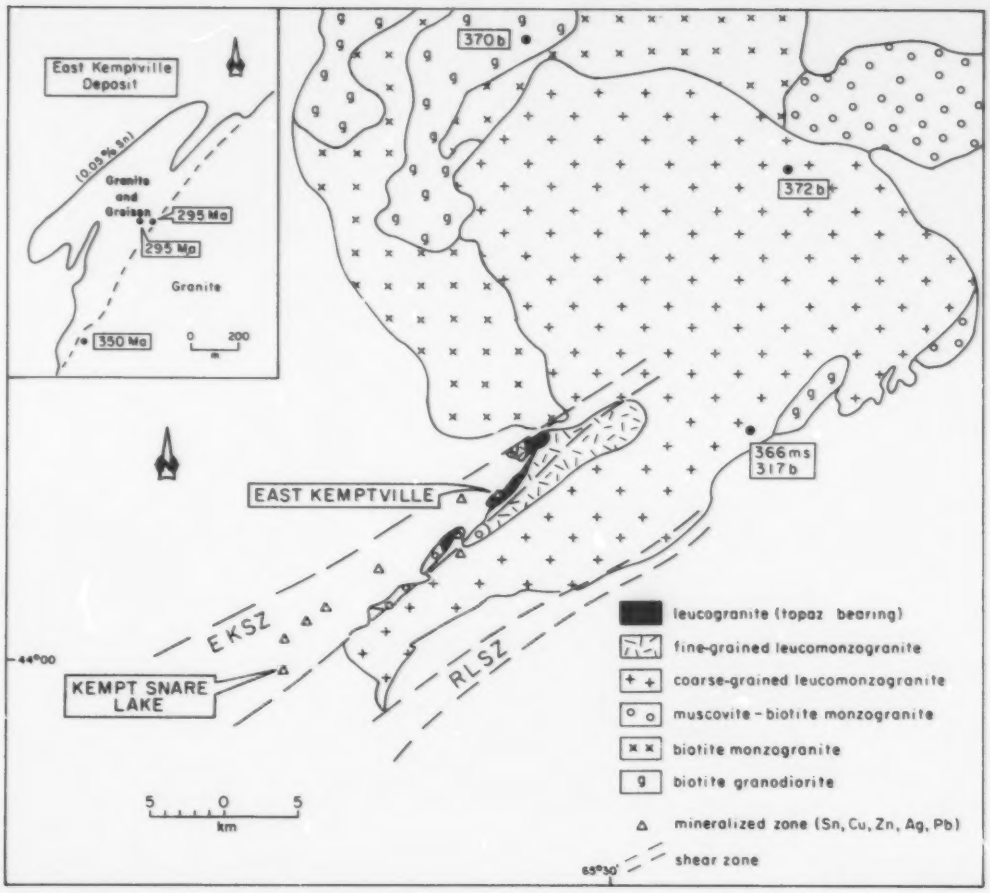


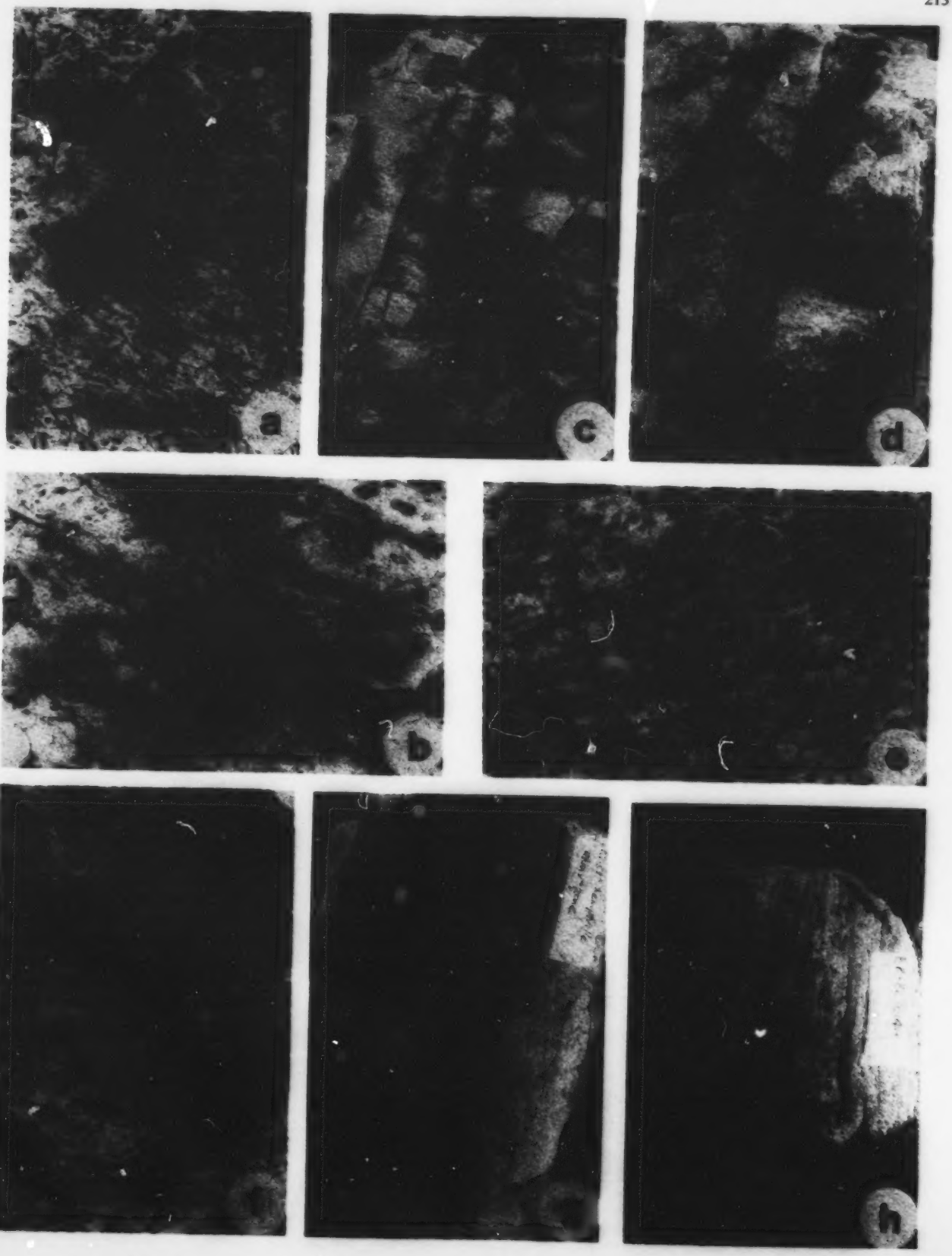
FIG. 3. Simplified geological map of the western part of the South Mountain Batholith, showing major subdivisions of the granitic lithologies (modified after MacDonald *et al.* 1989). Also shown are the following: (*i*) inset map of the East Kemptville deposit with the locations and results of the samples dated by Zentilli and Reynolds (1985) (note that the 0.05% Sn contour essentially corresponds to the leucogranite–metasediment contact (after Richardson *et al.* 1982)); (*ii*) outline of the East Kemptville shear zone (EKSZ) and Rushmere Lake shear zone (RLSZ); and (*iii*) locations of samples dated by Reynolds *et al.* (1981) using the $^{40}Ar/^{39}Ar$ technique (b, biotite; ms, muscovite).

(i.e., grain-size reduction) equivalent to the coarse-grained leucomonzogranite phase such that its present configuration reflects the extent of relatively intense deformation.

The outcrop pattern of the topaz–muscovite leucogranites, including the East Kemptville leucogranite, is distinctly northeast trending and the intrusions closely hug the granite–sediment contact rather than occur within the central part of the pluton (Fig. 3). This affiliation with a contact zone contrasts with, for example, the distribution of evolved granitoid phases within other plutons of the South Mountain Batholith (e.g., Halifax Pluton; MacDonald and Horne 1988).

Well-developed structural fabrics exist within the Davis Lake pluton, especially in the area designated the East Kemptville shear zone (Fig. 3 and see below). These fabrics vary from single planar features with numerous textural variations (e.g., spaced cleavage to blastomylonites) to C–S and C–C′–S structures in some places. The preferred sense of movement is dextral, but other offset directions have been

FIG. 4. Photographs of outcrops and hand specimens of various granitoid lithologies of the East Kemptville leucogranite taken within the open-pit area of the deposit. (*a*) Bedrock exposure of deformed leucogranite showing prominent development of northeast-trending, subvertically spaced cleavage; note that the very top of the photo shows undeformed leucogranite outside of the shear zone. (*b*) Detail of part of Fig. 4*a* (lower part of figure) showing the development of C–S fabrics within the leucogranite; note ten cent coin in lower left for scale. (*c*) Exposure of northeast-trending shear zone in leucogranite in northern part of the open-pit area (82 m level); note the sharp contact between relatively undeformed granite and intensely sheared equivalent. (*d*) Close-up of previous photo showing the sheared leucogranite; note the sharp contact between deformed and undeformed granite. (*e*) Cut slab of typical medium-grained, equigranular topaz–muscovite leucogranite; photo is approximately 10 cm wide. (*f*) Photo of northeast-trending shear zone of ~1–2 m width; granite within the shear zone displays a mylonitic texture. (*g*) Cut slab of intensely deformed greisenized granite displaying mylonitic texture; the fabric is oriented northeast and subvertical in the field (sample is ~10 cm wide). (*h*) Cut slab of intensely deformed, sericitized leucogranite; note the presence of a remnant piece of quartz–albite vein in the right side of sample indicating sense of shear; the fabric is northeast trending and subvertical in the field (sample is ~11 cm wide); fine dark grains aligned along the fabric are cassiterite.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noted (e.g., subvertical). As detailed kinematic studies remain to be done, more specific details are not warranted at present.

Previous dating within the Davis Lake pluton (Fig. 3) includes $^{40}Ar/^{39}Ar$ data of Reynolds *et al.* (1981) and Rb–Sr whole-rock and mineral analyses of Richardson *et al.* (1989). The $^{40}Ar/^{39}Ar$ work of Reynolds *et al.* indicated concordant mica dates of ca. 370 Ma except at a single locality within the Rushmere Lake shear zone where discordant results were obtained (i.e., 317 Ma biotite vs. 366 Ma muscovite; see Fig. 3). Rb–Sr whole-rock data for samples from the southern part of the Davis Lake pluton (30–35 km^2) presented by Richardson *et al.* indicated an isochron date of 330 ± 7 Ma. Although this date was significantly younger than $^{40}Ar/^{39}Ar$ mica dates from the same pluton, Richardson *et al.* interpreted the data as reflecting the crystallization age of the pluton. Four whole rock – biotite pairs gave an average Rb–Sr date of 247 Ma (range 236–257 Ma), which Richardson *et al.* considered to reflect open system behaviour of biotite during a subsequent tectonothermal event. In addition to this earlier work, more recent Pb-isotopic analyses of whole-rock samples from the Davis Lake pluton by A. K. Chatterjee (personal communication, 1989) indicate a date of ca. 368 Ma, which is interpreted as the time of intrusion and crystallization.

Geological setting and petrology of the East Kemptville leucogranite

The East Kemptville leucogranite is located within the East Kemptville shear zone, has an elongate shape, and occurs at the contact of the Davis Lake pluton and Meguma Group sedimentary rocks (Fig. 3). The presence of tongues of Meguma Group sediments extending into the granite and nonrotated rafts of sediments within the granite suggests close proximity to the original roof zone of the magma chamber. Although large parts of the leucogranite were greisenized during mineralizing processes, considerable parts of the same body appear as relatively fresh leucogranite (Fig. 4*e*), especially in areas removed from the granite–sediment contact.

The leucogranite is fine to medium grained, equigranular (Fig. 4*e*) and contains about 37% quartz, 30% albitic plagioclase, 20% microcline, 8% muscovite, and 5% topaz (Kontak 1990). The leucogranite is considered to represent a single intrusive phase since no internal contacts are observed as, for example, Kooiman *et al.* (1986) have documented at Mount Pleasant, New Brunswick. Hence, the textural variations observed are interpreted to reflect local fluctuations in physiochemical conditions. The absence of fluid saturation textures, such as miarolitic cavities or crenulate layers, is noted in light of suggestions by Richardson *et al.* (1988) that fluid-saturation was prevalent. Observation over a 4 year period of open pit development indicates that pegmatites are very rare, being localized to granite–sediment contact zones and limited to only a few localities. More details of the petrography and chemistry of the leucogranite are given elsewhere (Kontak 1987*a*, 1990).

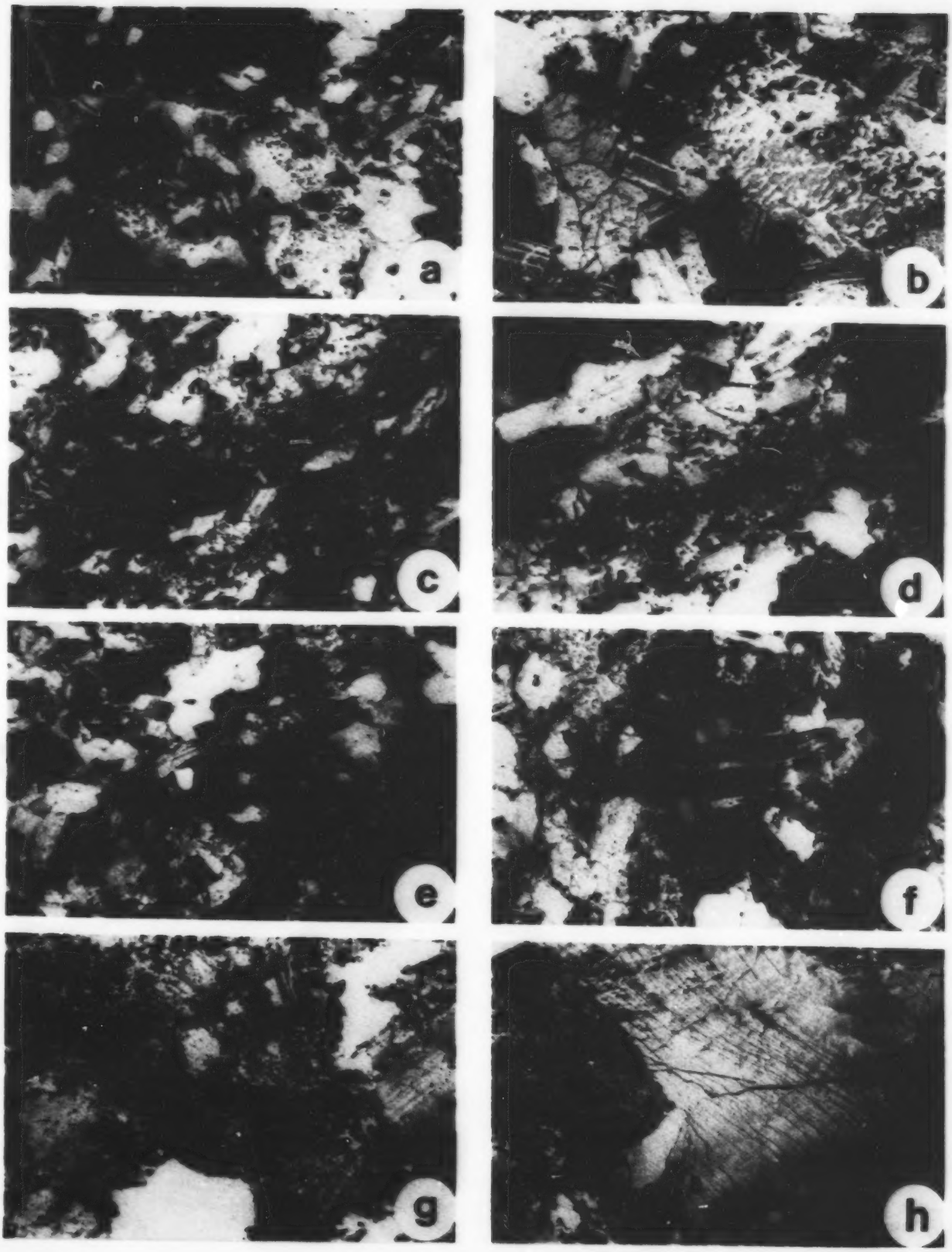
Intensely developed structural fabrics within the leucogranite can be observed on both the macro- and micro-scopic scale. In outcrop, northeast-trending fabrics range from spaced cleavage through to blastomylonites (Figs. 4*a*–4*d*, 4*f*–4*h*) and clearly postdate the mineralizing event (Figs. 5*g*, 5*h*). Well-defined shear zones exhibit sharp contacts between the high-strain zone and relatively undeformed leucogranite (Figs. 4*c*, 4*d*, 4*f*). The degree of structural overprinting is highly variable, even on a local scale, but some of the mylonitic zones are 1–2 m in width and at least 100–200 m in length. There appears to be a strong preference for more intense development of deformation within phyllically altered rock (Fig. 4*h*). In thin section, deformational fabrics are invariably present (Fig. 5), even in rocks that appear pristine in the field (Fig. 4*e*). Structural modification of primary magmatic mineral phases includes recrystallization of quartz (Fig. 5*d*) and development of shear bands (Fig. 5*h*), kinking of muscovite with some recrystallization along grain margins (Fig. 5*g*), fracturing and bending of twin planes in albite (Fig. 5*f*), fracturing of topaz (Fig. 5*b*), and probable inversion of K-feldspar from orthoclase to fully ordered microcline (i.e., $t_1O = 1.0$; Kontak, unpublished data). Spaced fractures are common in most specimens (Figs. 5*a*, 5*c*, 5*e*) and where deformation is most intense, as in mylonites, a laminated texture is developed. As observed in field relationships, the degree of textural modification seen in thin section is also highly variable.

Previous dating at East Kemptville has been summarized above and in Fig. 2. However, additional data relevant to this study include recent Pb isotopic data for both leucogranite and greisens at the deposit (A. K. Chatterjee, personal communication 1990). These data indicate that intrusion, crystallization, and mineralization were essentially coincident at ca. 368 Ma. In addition, the data all regress to the same slope as Pb isotope data for the Davis Lake pluton referred to previously.

Sample selection and analytical procedures

Eleven samples of the East Kemptville leucogranite, representing the maximum textural and chemical variation with respect to magmatic and deuteric processes, were collected from an area of ~0.4 km^2. Samples that showed signs of intense deformation on the macro- and micro-scopic scale were intentionally avoided, but as discussed above the penetrative nature of the deformation means that no sample is totally devoid of deformational fabrics. With respect to the samples collected, the following points are noted: (*i*) EK-86-132 comes from the northern part of the deposit area where a tongue of leucogranite extends into the sediment; this sample contains negligible effects of deformation, but no trace of K-feldspar remains due to deuteric alteration (i.e., replacement by secondary muscovite); (*ii*) EK-86-98 represents a pegma-

FIG. 5. Photomicrographs of East Kemptville leucogranite showing typical textures. (a) Representative photomicrograph of relatively undeformed sample (EK-86-69); note the good igneous textures and equigranular grain size; however, spaced fractures that trend horizontal are also evident (~26 mm width). (*b*) Enlargement of central part of the previous photo showing the subhedral outline of fractured topaz (left side of photo) and perthitic nature of microcline (bulk composition is Or_{82}–Ab_{17}–An_1; ~8 mm width). (*c*) Moderately deformed leucogranite (EK-86-09) with spaced fractures throughout (~26 mm width). (*d*) Enlargement of central part of previous photo showing recrystallization of quartz grain (~8 mm width). (*e*) Moderately deformed leucogranite (EK-86-72) showing irregular network of fractures throughout (~26 mm width). (*f*) Photo of deformed albite grain surrounded by undulose quartz, sericitic alkali feldspar, and albite (sample EK-86-72; ~8 mm width). (*g*) Sample (EK-86-105) containing primary muscovite (ms) displaying development of pressure bands (~8 mm width); note the presence of finer grained secondary muscovite. (*h*) Series of subparallel spaced fractures cutting coarse quartz grain in pegmatite sample (EK-86-98); large grain to the left of quartz is sericitized albite (~26 mm width).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tite–aplite sample from the stockscheider outcrop referred to in Richardson *et al.* (1988); (*iii*) EK-86-1075B is from the northwest granite–sediment contact; however, the sample is free of any textural indication of rapid cooling; (*iv*) EK-89-1 comes from the extreme south end of the deposit area where the deepest mining activity had progressed (56 m level) as of August 1989; (*v*) EK-86-105 is a greenish felsite dyke rock cutting coarser leucogranite. (*vi*) EK-86-124B is a sample of leucogranite peripheral to a zoned greisen (1–2 m). The remaining specimens are typical leucogranite samples from both exposures within the pit area and from ore piles.

The 11 whole-rock samples used for Rb–Sr analyses were crushed to −2 to −3 cm and quartered, with one fraction crushed to −200 mesh and another crushed and sieved for mineral separation (−40 to +80 mesh fraction). Mineral separates (K-feldspar, muscovite, quartz–plagioclase) were prepared employing standard procedures of magnetic and heavy liquid separation. All mineral separates analyzed come from the same mesh size, except in a few cases where insufficient muscovite was obtained and additional material was required (−80 to +120 mesh fraction). A high quality muscovite separate (−60 to +80 mesh) was prepared from sample EK-86-132 for $^{40}Ar/^{39}Ar$ analysis using similar techniques of mineral separation. The following abbreviations are used while discussing the analytical results: WR, whole rock; WRMMS, whole rock minus the muscovite fraction; QP, quartz–plagioclase fraction; KF, K-feldspar fraction; MS, muscovite fraction.

Methods for Rb–Sr and $^{40}Ar/^{39}Ar$ analyses are identical to those fully described by Cormier *et al.* (1988) and Reynolds *et al.* (1987), respectively. Errors assigned for uncertainties (2 σ) in the $^{87}Rb/^{86}Sr$ and $^{87}Sr/^{86}Sr$ ratios, based on replicate analyses (n = 40) of the National Bureau of Standards NBS-70a K-feldspar standard, were 3.0 and 0.3%, respectively. All errors are quoted at the 95% confidence level, and decay constants employed are those recommended by Steiger and Jager (1977).

Results

Rb–Sr analyses

Results of Rb–Sr analyses are presented in Table 1, and calculated dates, errors, initial $^{87}Sr/^{86}Sr$ ratios, and statistical parameters are provided in Table 2. The whole-rock (n = 11), whole-rock minus muscovite (n = 9) and muscovite (n = 7) data have been regressed using the method of York (1966), with the mean square weighted deviates values (MSWD) calculated according to McIntyre *et al.* (1966) and the F-values taken from Brooks *et al.* (1972) based on the appropriate number of duplicate samples analyzed.

Data obtained from the 11 whole-rock samples, plotted in an isochron diagram in Fig. 6*a*, indicate a date of 344 ± 5 Ma with a $^{87}Sr/^{86}Sr$ initial ratio of 0.7245 ± 0.0056. The scatter of the data is well within analytical uncertainty, with the MSWD = 1.26 and F-value = 2.72, hence the data define an isochron (Brooks *et al.* 1972).

The data for nine whole-rock samples analyzed after removal of their muscovite fraction are plotted in an isochron diagram in Fig. 6*b*. Regression of the data indicates a date of 354 ± 13 Ma, with an $^{87}Sr/^{86}Sr$ initial ratio of 0.7215 ± 0.0107. The statistics associated with regression (MSWD ± 9.02, F-value = 2.83) indicate that the data define an errorchron rather than an isochron.

Muscovite separates extracted from seven whole-rock samples were also analyzed, and regression of the data indicate a date of 320 ± 4 Ma, with an initial $^{87}Sr/^{86}Sr$ ratio of 0.7519 ± 0.0320 (isochron plot in Fig. 6*c*). The statistics of this regression (MSWD = 3.00, F-value ± 3.03) indicate that the associated errors are within analytical uncertainties and the regression line defines an isochron.

The data from analyses of the WR, WRMMS, and MS from

TABLE 1. Rb–Sr analytical data for East Kemptville leucogranite

Sample	Rb	Sr	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
EK-86-161				
MS	5200	32.2	594	3.4349
Kf	1950	40.3	150	1.4266
WR	973	18.9	160	1.5082
WRMMS	570	16.1	108	1.2733
QP	245	9.57	77.3	1.1657
EK-86-1075B				
MS	4510	106	132	1.3703
KF	1600	41.7	116	1.2211
WR	858	32.2	80.3	1.1103
WRMMS	386	21.7	53.0	0.9809
QP	269	19.3	41.2	0.9404
EK-86-132				
MS	2380	104	68.5	1.0708
WR	663	96.6	20.1	0.8223
WRMMS	72.2	61.7	3.77	0.7369
EK-86-023C				
MS	4840	253	58.8	1.0175
KF	1820	141	38.0	0.9092
WR	971	77.8	38.3	0.9217
WRMMS	473	51.9	26.8	0.8687
QP	256	36.0	20.9	0.8490
EK-89-1				
MS	5400	17.6	1490	7.6119
KF	1230	42.2	87.8	1.1465
WR	739	24.8	90.0	1.1705
WRMMS	368	19.1	57.5	1.0273
QP	227	17.6	38.4	0.9620
EK-86-156				
MS	4360	37.6	397	2.5811
KF	1050	77.7	40.3	0.8959
WR	779	70.7	32.4	0.8821
WRMMS	420	50.9	24.2	0.8392
QP	269	45.9	17.1	0.8171
EK-86-124B				
KF	1600	29.8	166	1.4075
WR	1220	34.1	109	1.2615
WRMMS	504	20.0	75.7	1.0919
QP	386	19.0	60.6	1.0337
EK-86-009				
KF	1920	40.2	147	1.3749
WR	926	31.5	89.0	1.1614
WRMMS	588	23.0	76.9	1.1050
QP	470	21.7	64.8	1.0503
EK-86-105				
MS	4110	267	45.7	0.9366
WR	751	236	9.28	0.7680
WRMMS	246	112	6.35	0.7561
EK-86-072				
WR	866	60.5	42.3	0.9238
EK-86-098				
WR	340	75.8	13.1	0.7926

NOTES: WR, whole rocks; MS, muscovite; KF, K-feldspar; QP, quartz–plagioclase; WRMMS, whole rock minus muscovite.

TABLE 2. Age, initial $^{87}Sr/^{87}Sr$ ratios, and statistical data for East Kemptville leucogranite samples

Material regressed	No. of samples	Age (Ma ± 1σ)	$^{87}Sr/^{86}Sr$ ±1σ	MSWD	*F*-value
Whole rocks	11	344±5	0.7245±0.0056	1.26	2.72
Whole rocks minus muscovite	9	354±13	0.7215±0.0107	9.02	2.83
Muscovites	7	320±4	0.7519±0.0320	3.00	3.03
Whole rock / muscovite / whole rock minus muscovite					
EK-86-132	3	361	0.718		
EK-86-1075B	3	342	0.723		
EK-86-023C	3	330	0.741		
EK-86-156	3	326	0.730		
EK-89-1	3	322	0.741		
EK-86-105	3	320	0.726		
EK-86-161	3	311	0.800		
Quartz / plagioclase / K-feldspar / whole rock minus muscovite					
EK-86-009	3	276	0.800		
EK-86-1075B	3	263	0.783		
EK-89-1	3	260	0.818		
EK-86-161	3	251	0.887		
EK-86-023C	3	247	0.775		
EK-86-124B	3	245	0.825		
EK-86-156	3	240	0.758		

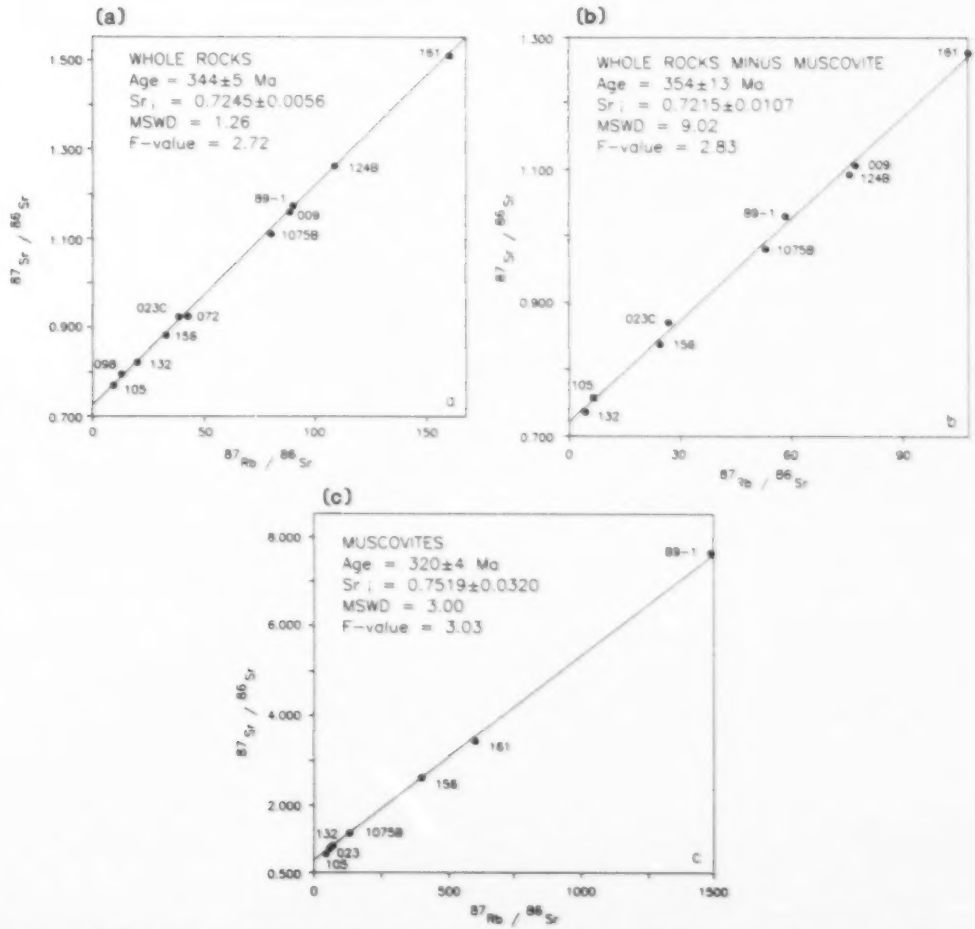

FIG. 6. $^{87}Sr/^{86}Sr$ vs. $^{87}Rb/^{86}Sr$ isochron plots for the East Kemptville leucogranite: (*a*) whole-rock samples; (*b*) whole rock(s) minus muscovite fraction (i.e., essentially quartz and feldspars) (note that the data do not statistically define an isochron); and (*c*) muscovite separates.

TABLE 3. $^{40}Ar/^{39}Ar$ analytical data for sample EK-86-132 muscovite

Temp. (°C)	$^{39}Ar/^{36}Ar$	$^{40}Ar/^{36}Ar$	$^{39}Ar_K$ (% total)	$^{40}Ar_R$ (%)	Age (Ma ± 1σ)
600	12.9	1299	4	77	286±3
650	18.1	1615	2	82	269±3
700	24.7	2171	3	86	281±2
750	16	1541	3	81	286±3
780	63.1	5712	15	95	314±3
810	9.8	1066	2	72	288±3
840	26	2480	3	88	307±3
870	77.6	7490	41	96	337±3
900	43.6	4389	21	93	341±2
950	9.4	1161	4	75	334±2
1000	2.8	533	2	45	311±8

NOTES: Integrated age = 326 Ma; *J*-value = 0.00222.

seven samples have been used to calculate dates and initial $^{87}Sr/^{86}Sr$ ratios (Table 2). It should be noted that the data do not strictly define isochrons, since there are only two mineralogically distinct phases (i.e., WRMMS and MS), with the third data point (WR) being a mixture of the other two. The data indicate a range in dates from a maximum of ca. 361 Ma to a minimum of ca. 311 Ma, with initial $^{87}Sr/^{86}Sr$ values that are lowest for the sample with the oldest apparent age and highest for the sample with the youngest apparent age. Age calculations using just the whole-rock and muscovite data give identical dates, with the exception of sample EK-86-1075B for which a date of 353 Ma is calculated using only the whole rock – muscovite data (*versus* 342 Ma using the WR–WRMMS–MS data).

The Rb–Sr systematics of WRMMS-QP-KF in seven samples have also been examined, with calculated dates and initial $^{87}Sr/^{86}Sr$ ratios provided in Table 2. As with the previous data, we note that these data do not define isochrons, since only two mineralogically distinct phases are represented (i.e., QP and KF), with the third (WRMMS) being a mixture of these. The data for the seven samples indicate similar ages, which range from a maximum of 276 to a minimum of 240 Ma.

$^{40}Ar/^{39}Ar$ results

Results for step heating of sample EK-86-132 are presented in Table 3, and the data are plotted in a conventional $^{40}Ar/^{39}Ar$ age spectrum diagram in Fig. 7. The age spectrum is clearly discordant, with the gas fractions broadly defining three parts. The initial 12% of the gas (four steps with extraction temperatures of 600–750°C) indicate an apparent age of ca. 280 Ma, although one of these steps is notably younger (269 Ma) than the other three. This initial low-temperature gas release is followed by a single step in the spectrum that accounts for 15% of the total gas release and has an apparent age of 314 Ma. Following two small fractions (i.e., 2–3%) of gas, which again give low apparent ages (288 and 307 Ma), there is a large portion of gas (62%) released in two steps (870 and 900°C) which define a plateau date of 338.3 ± 2 Ma using the criteria of Fleck *et al.* (1977). The rapid decrease in apparent age for the last two steps with a concomitant increase in the atmospheric component remains unresolved; hence, it is difficult to interpret the significance of these last steps.

An alternative way to examine the release spectrum of this muscovite separate (EK-86-132) is to divide it into two broad

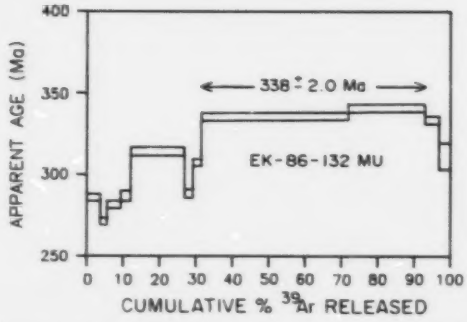

FIG. 7. Conventional $^{40}Ar/^{39}Ar$ age spectrum plot for EK–86–132 muscovite separate.

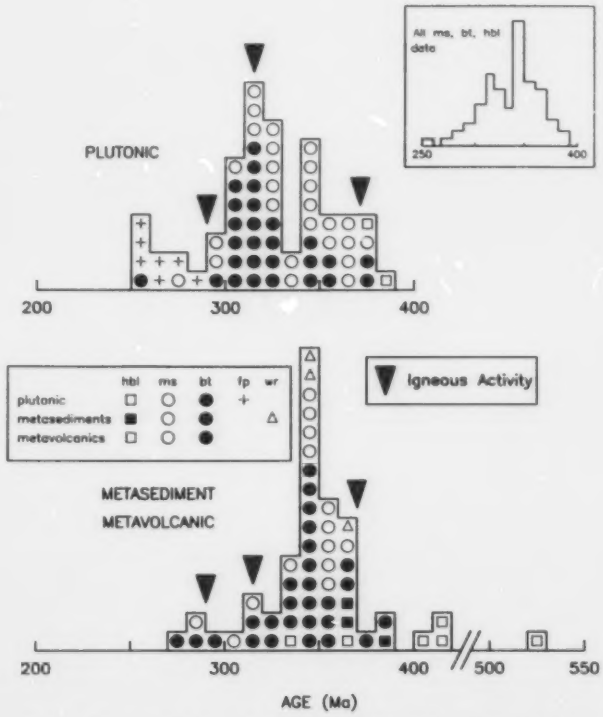

FIG. 8. Composite plot of all available $^{40}Ar/^{39}Ar$ geochronological data for southwestern Meguma Terrane. Sources of data include Reynolds *et al.* (1981), Zentilli and Reynolds (1985), Dallmeyer and Keppie (1987, 1988), and Muecke *et al.* (1988). The ages of intrusive activity have been inferred from the work of Cormier *et al.* (1988), on the Wedgeport pluton (315 Ma), J. D. Keppie (personal communication, 1989) for the Shelburne and Barrington Passage Plutons (372 Ma) and Dallmeyer and Keppie (1987, 1988) for an unexposed subsurface pluton south of Sable Island (ca. 290 Ma). bt, biotite; fp, feldspar; hbl, hornblende; ms, muscovite; wr, whole rock.

parts, namely steps 1–5 and the remainder. In this case, the "two-pulsed" nature of the muscovite has the characteristics of the "two-faced" spectra described by York and Lopez-Martinez (1986).

Discussion

Collectively, the Rb–Sr and $^{40}Ar/^{39}Ar$ data outline a broad range of apparent ages (ca. 354–240 Ma) for the East Kemptville leucogranite. We are concerned, therefore, with resolving the dilemma of what the significance is of the dates obtained

and trying to relate the dates to various geological phenomena. Interpretations of the Rb–Sr and $^{40}Ar/^{39}Ar$ analytical data are discussed separately.

Interpretation of Rb–Sr data

The Rb–Sr isotopic data for the East Kemptville leucogranite are interpreted with the following constraints in mind: (*i*) the ca. 368 Ma Pb-isotope age for both the Davis Lake pluton and the East Kemptville leucogranite and associated mineralization; (*ii*) the geology of the South Mountain Batholith which demonstrates a continuum in lithologic units throughout (see MacDonald *et al.* 1989); hence, the nature of the batholith suggests a similar age for all lithological units contained within it; (*iii*) results of previous geochronological studies (Rb–Sr, K-Ar, and $^{40}Ar/^{39}Ar$; Clarke and Halliday 1980; Reynolds *et al.* 1981, 1987) that together indicate intrusion of all phases of the batholith at ca. 370 Ma; and (*iv*) the minimum age of ca. 350 Ma inferred from one of the $^{40}Ar/^{39}Ar$ muscovite age spectra produced by Zentilli and Reynolds (1985). Using the aforementioned constraints, we interpret the Rb–Sr data in the following manner:

(1) The whole-rock age of 344 ± 5 Ma may be interpreted to indicate the time of initial intrusion and crystallization of the leucogranite or, alternatively, it may reflect the age of a rehomogenization event (with respect to the Rb–Sr isotopic system). The latter scenario, involving open-system behaviour of Sr and (or) Rb on the whole-rock scale, is considered a more likely interpretation given the constraints summarized above. We cannot determine, however, the time frame of the event responsible for the rehomogenization (i.e., long vs. short term) or if several such events may have occurred.

(2) The 354 ± 13 Ma date indicated by regression of the WRMMS data does not define a statistically valid isochron, and the associated error overlaps the 344 Ma whole-rock age; hence, the two dates may be considered as being broadly equivalent. The large associated errors (MSWD = 9.02) may reflect disequilibrium among the feldspar fractions of the different samples, since subsequent tectono-thermal events are known to have variably affected this mineral fraction (Table 2 and below).

(3) The 320 ± 4 Ma date indicated by regression of the muscovite data defines a statistically valid isochron. It is difficult, however, to reconcile the validity of this data in light of the 344 Ma Rb–Sr whole-rock isochron age. For example, the whole-rock data indicate that at 344 Ma isotopic equilibrium was attained on both the whole-rock and mineral scale. By 320 Ma each whole rock would have had a different $^{87}Sr/^{86}Sr$ value and muscovite should have been in equilibrium with Sr in the individual rock. Therefore, it is difficult to rationalize the muscovite isochron date knowing that at 320 Ma the muscovites should not have had similar $^{87}Sr/^{86}Sr$ initial ratios, as implied by the isochron. We have no explanation for this apparently fortuitous, but statistically valid, muscovite isochron date.

(4) The variable WR–WRMMS–MS, or similarly WR–MS, dates that range from 361 to 311 Ma are interpreted to reflect internal reequilibration of the whole-rock samples in response to tectono-thermal activity. It is perhaps significant to note that samples EK-86-132 and EK-86-1075B, which have the oldest ages, are less deformed with respect to their petrofabrics compared with other samples. The spread of dates presumably reflects either a protracted time period for the processes responsible for the isotopic reequilibration or variable amounts of isotopic reequilibration for the individual samples. For example, although the data set is limited to seven samples, there is a convergence at ca. 320–330 Ma which may represent the true time of the event, with older ages merely reflecting partial reequilibration. Presumably the WR–MS Rb–Sr dates also indicate the time of last cooling through temperatures required for intracrystalline retention of Sr within muscovite. These temperatures have not been calibrated experimentally, but based on comparisons with other geochronological studies a temperature of ca. 500°C has been suggested (e.g., Purdy and Jager 1976; Jager 1979).

(5) The youngest dates, ranging from 276 to 240 Ma, are for the QP–KF–WRMMS data. Again, these data are interpreted to reflect reequilibration on the whole-rock scale, but such that only the feldspar fraction (i.e., K-feldspar and albitic plagioclase) has been affected. As with the WR–WRMMS–MS dates, the range of dates records either a protracted time interval during which the reequilibration occurred or variable degrees of reequilibration. Although it is difficult to extract a single, representative age from this data set, we tentatively subscribe to the average age of 254 ± 20 Ma (2σ error about the mean) for purposes of discussion and reference.

Interpreted collectively, the Rb–Sr data indicate a spread of dates such that a progressive decrease is indicated for the whole rocks, whole rocks – muscovite and whole rocks – feldspar. This progression is consistent with the Rb–Sr isotopic systematics if thermal processes were responsible for the reequilibration (Jager 1979). It would, however, be premature to interpret the data as representing a single protracted thermal event, since alternative interpretations are possible. For example, three distinct thermal (and tectonic) events may have occurred at ca. 344, 320–330, and 254 Ma, with the intervening periods characterized by relatively dormant tectono-thermal activity.

Interpretation of the $^{40}Ar/^{39}Ar$ data

The $^{40}Ar/^{39}Ar$ age spectrum for muscovite sample EK-86-132 indicates a complex thermal evolution that must be interpreted with caution, while also keeping in mind the ca. 361 Ma WR–WRMMS–MS Rb–Sr date for this same sample (Table 2). If the age spectrum is considered to reflect outgassing of a single mineral phase, as opposed to a mixture of different white mica phases (see below; cf. Wijbrans and McDougall 1986), and is interpreted as a diffusion profile in the sense of Turner (1968), then the data suggest (*i*) a minimum age of ca. 280 Ma for an overprinting event as indicated by the apparent dates of the lower temperature release steps, and (*ii*) a minimum age of 338 Ma (i.e., plateau segment) for crystallization of the muscovite. However, if as discussed above, the age of the leucogranite and associated mineralization is ca. 368 Ma, then the apparent plateau age of 338 Ma must also reflect a resetting event.

An alternative way of interpreting the age spectrum is in terms of either (*i*) a mixture of two distinct phases as, for example, Wijbrans and McDougall (1986) have demonstrated for samples from Naxos, Greece, or (*ii*) as two distinct domains releasing Ar as in the "two-faced" model of York and Lopez-Martinez (1986). Petrographic observations indicate the dominance of a single muscovite, although lesser amounts (<5 %) of finer grained muscovite are present, and microprobe analyses indicate a similar chemistry for the different textural varieties (D.J. Kontak, unpublished data). Thus, while the first

alternative can probably be eliminated based on the latter observations, we cannot at present rule out the second possibility.

The foregoing discussion of the muscovite age spectrum is summarized as follows. The ca. 338 Ma plateau segment reflects an event of sufficient temperature (i.e., ≥350°C) and duration to completely outgas the muscovite, which presumably first formed at ca. 368 Ma. However, the ca. 361 Ma Rb–Sr WR–MS age for this sample suggests that the temperature attending this event must have been less than the temperature required for intracrystalline diffusion of Sr in muscovite (i.e., 500°C). The discordance of the age spectrum in the low temperature steps reflects a later thermal event (at ca. 280 Ma) that was of either insufficient temperature or duration to cause complete diffusion of Ar within the crystalline structure of the muscovite. Although this latest thermal event is poorly constrained, its presence is corroborated by the WR–QP–KF Rb–Sr ages discussed above.

Comparison of results with previous dating of the East Kemptville deposit and immediate area

Results of the present study provide insight into earlier Rb–Sr and $^{40}Ar/^{39}Ar$ data published for the East Kemptville deposit by Richardson *et al.* (1988) and Zentilli and Reynolds (1985), respectively. The 337 ± 5 Ma Rb–Sr whole-rock isochron age for the quartz–topaz greisen obtained by Richardson *et al.* corresponds to the 344 ± 5 Ma Rb–Sr whole-rock date reported here for the leucogranite; similarly, the initial $^{87}Sr/^{86}Sr$ ratios are coincident within experimental error. However, as the above discussion indicates, we do not subscribe to the interpretation of Richardson *et al.* (1988) and, instead, interpret the date as representing a reequilibration event.

The $^{40}Ar/^{39}Ar$ data of Zentilli and Reynolds (1985) are also more easily reconciled in light of our recent geological and geochronological work. The samples analyzed all contained deformational fabrics, as described by the authors, and when combined with the above geochronological data indicate that they have dated not the age of intrusion or attendant hydrothermal alteration and mineralization, as they state, but subsequent tectono-thermal activity. The coincidence of the older plateau age of ca. 350 Ma, recorded by one of the muscovite samples analyzed by Zentilli and Reynolds, with the Rb–Sr whole-rock age of 344 ± 5 Ma reflects simultaneous closure of the whole rocks to Sr diffusion and muscovite to Ar diffusion. In light of our interpretation of the Rb–Sr whole-rock date as discussed previously, this ca. 350 Ma apparent plateau age is considered to represent a time of postcrystallization Ar diffusion and not an original time of granitic intrusion and crystallization.

We have at present no satisfactory explanation as to why the four muscovite $^{40}Ar/^{39}Ar$ age spectra obtained from the East Kemptville deposit area are so different, especially considering the small sampling area, but suggest some potential contributing factors. First, there are large differences in the Fe contents (2–14 wt.% FeO; Ham and Kontak 1988; D.J. Kontak unpublished data) of the primary magmatic and greisen muscovites. If, for example, this parameter is as important in muscovite as it is in biotite (Harrison *et al.* 1985) and amphibole (Onstott and Peacock 1987; O'Nions *et al.* 1969; but also see Harrison 1981), then compositional differences may be a contributing factor. Second, there is a wide spectrum of grain sizes both within and between samples. Again, this is known to be an important parameter both from theoretical considerations (Dodson 1973; Jager 1979) and from natural examples (e.g., Berger and York 1979). A third and final consideration, although perhaps not as important as the first two, is grain-edge morphology. Reuter and Dallmeyer (1987) found that in fine-grained sericite this could potentially be an important parameter because of the extent of recoil loss of ^{39}Ar. A more detailed $^{40}Ar/^{39}Ar$ study of muscovite from East Kemptville is currently under way to resolve this problem.

Additional geochronological data from the vicinity of the East Kemptville area that can be reconsidered in light of the above discussion include the following:

(1) The 330 ± 7 Ma Rb–Sr whole-rock isochron age for the Davis Lake pluton, which Richardson *et al.* (1989) interpreted as indicating a time of intrusion and crystallization. We disagree with Richardson *et al.*'s interpretation of the Rb–Sr data for the following reasons: (*i*) previously published $^{40}Ar/^{39}Ar$ data (Reynolds *et al.* 1981) for micas from different parts of the Davis Lake pluton (see Fig. 3) indicating a 370 Ma age; (*ii*) the oldest muscovite sample reported by Zentilli and Reynolds (1985) at East Kemptville indicates a minimum age of ca. 350 Ma for the Davis Lake pluton; (*iii*) the recent Pb-Pb whole-rock isochron age of 368 Ma obtained for the Davis Lake pluton (A. K. Chatterjee, personal communication, 1990); and (*iv*) geological considerations (MacDonald *et al.* 1989) indicating that the Davis Lake pluton represents part of the ca. 370 Ma South Mountain Batholith. In light of this new interpretation, the scatter of the data set (i.e., only five of the eight samples analyzed were included in the regression) might now be related to incomplete reequilibration of Sr during subsequent tectono-thermal activity. In addition, the contention of Richardson *et al.* (1987, p. 819) that the 330 Ma age for the Davis Lake pluton represents "...the first well-documented igneous pluton within the 'suspect' Meguma Terrane that can be easily related to the Carboniferous Alleghanian orogeny" is negated. Instead, the Wedgeport Pluton of ca. 315 Ma (concordant U–Pb zircon and Rb–Sr whole-rock ages) dated by Cormier *et al.* (1988) must be granted this distinction.

(2) The young Rb–Sr whole rock – biotite ages of 236–257 Ma reported in Richardson (1988a) and Richardson *et al.* (1989). These young ages reflect the same tectono-thermal event as the Rb–Sr whole rock – feldspar ages obtained at East Kemptville (276–240 Ma). The coincidence of these ages indicates that the minimum temperatures associated with this disturbance must have been higher than that required to reset Rb–Sr biotite ages (≥300°C) but below that required to reset the muscovite Rb–Sr ages (ca. 500°C) as recorded at East Kemptville (Purdy and Jager 1976; Dodson 1979; Harrison and McDougall 1980).

(3) The young muscovite and K-feldspar $^{40}Ar/^{39}Ar$ ages obtained by Soehl *et al.* (1989) from the nearby Kempt Snare Lake greisenized granite cupola (see Fig. 3). The two muscovite samples analyzed had internally discordant age spectra, which would be consistent with an overprinting event at ca. 265 Ma; the higher temperature steps showed continued stepping up to maximum apparent ages of ca. 300 Ma and 330 Ma. In contrast with muscovite spectra, a single K-feldspar spectrum showed a somewhat more consistent age profile, with individual steps giving apparent ages of 240–260 Ma. The $^{40}Ar/^{39}Ar$ ages reported by Soehl *et al.* (1989) are, therefore, broadly coincident with ages inferred for tectono-thermal events at East Kemptville based on both Rb–Sr and $^{40}Ar/^{39}Ar$ analyses.

Regional synthesis of tectono-thermal and magmatic events in the southern Meguma Terrane

The geochronological data for the southwestern South Mountain Batholith discussed above can be interpreted with respect to a compilation of available U–Pb, Rb–Sr, and $^{40}Ar/^{39}Ar$ data from the southern Meguma Terrane (O'Reilly *et al.* 1985; Reynolds *et al.* 1981, 1987; Dallmeyer and Keppie 1987, 1988; Cormier *et al.* 1988; Muecke *et al.* 1988; J. D. Keppie, personal communication, 1989). The $^{40}Ar/^{39}Ar$ data are compiled in Fig. 8 and the following points are noted:

(1) There are three magmatic events recognized at ca. 370 Ma (South Mountain Batholith, Shelburne Pluton, and Barrington Passage Pluton), ca. 315 Ma (Wedgeport Pluton), and ca. 290 Ma (unexposed pluton south of Cape Sable Island; Dallmeyer and Keppie 1988). However, the 370 Ma event is by far the most prominent and the most significant with respect to metallogeny.

(2) Although there is a large spread for both groupings of data (i.e., plutonic vs. metasedimentary–metavolcanic rocks), there is a distinct difference in the concentration of ages in the respective histograms. Whereas there appears to be a unimodal distribution for the metasediment and metavolcanic rock data (350 ± 10 Ma), there appear to be at least two distinct peaks in the data for plutonic rocks (ca. 320 and ca. 350–360 Ma). If the entire data set is combined into a single histogram (inset in Fig. 8), then these two apparent peaks become more obvious. The ca. 350 and event is coincident with the Rb–Sr whole-rock age (344 ± 5 Ma) and maximum $^{40}Ar/^{39}Ar$ muscovite ages (350 Ma, 338 Ma) recorded at East Kemptville and, therefore, suggests a fairly pervasive thermal event at this time in the southern part of the Meguma Terrane. Although this latter event cannot be correlated with any known igneous activity, the coincidence of the second event of ca. 315 Ma age with the time of emplacement of the Wedgeport Pluton (i.e., 315 Ma: Cormier *et al.* 1988) suggests such a connection.

(3) The distinct tailing of age data in the histogram plots reflects the youngest thermal event at 300 Ma. The relatively more localized nature of this thermal, or possibly magmatic (Dallmeyer and Keppie 1988), event is suggested by the general paucity of ages in this range. However, comparatively lower temperatures attending this event might also be an explanation for the general paucity of dates in this range since the histograms are based on $^{40}Ar/^{39}Ar$ mica ages. Again, this event is represented at East Kemptville by Rb–Sr whole rock – feldspar ages and some of the $^{40}Ar/^{39}Ar$ age spectra. Cormier *et al.* (1988) also recognized this event in the Wedgeport pluton based on Rb–Sr whole rock – mineral (biotite, K-feldspar, plagioclase) dates which average 257 ± 8 Ma.

East of the study area, O'Reilly *et al.* (1985) reported some anomalously young ages for mineralized centres within the South Mountain Batholith (see Fig. 1 for locations). The ages obtained, based on the Rb–Sr whole-rock technique, were 332 ± 10 Ma (MSWD = 1.53, $n = 6$) and 270 ± 14 Ma (MSWD = 1.21, $n = 5$) for the Long Lake (Mo, W) and Westfield–Caledonia (W, Au) properties, respectively. In addition, a Rb–Sr muscovite age (greisen) of 281 ± 5 Ma was obtained for the Lake Darling Cu prospect. These apparent ages are coincident with dates obtained in the southern Meguma Terrane, both at East Kemptville and on a more regional basis. Thus, the ages reported by O'Reilly *et al.* (1985) are interpreted to reflect the influence of tectono-thermal events. We further emphasize the proximity of two of the three aforementioned localities to the East Kemptville – East Dalhousie Fault Zone and the Tobeatic fault zone (Fig. 1). Although the Long Lake area is removed from these major fault zones, the anomalously young age suggests the influence of, and hence possible proximity to, another structure. These occurrences have also been discussed recently by Richardson *et al.* (1989) in conjunction with their data on the Davis Lake Complex to infer the presence of widespread Carboniferous magmatism in the Meguma Terrane. Our interpretation of the data is in marked contrast to that of Richardson *et al.* (1989), and we note that detailed mapping of these areas indicates continuity of the granitoid lithologies with the rest of the South Mountain Batholith (MacDonald *et al.* 1989). Hence, the evidence is not for the widespread ca. 330 Ma Carboniferous magmatic event in the Meguma Terrane postulated by Richardson *et al.* (1989) but rather for widespread resetting due to tectono-thermal events.

Additional Rb–Sr whole-rock and mineral ages (Clarke and Halliday 1980; Cormier and Smith 1973) and $^{40}Ar/^{39}Ar$ mica and feldspar ages (Reynolds *et al.* 1981, 1987) for the eastern half of the South Mountain Batholith indicate coincident dates of ca. of 370 Ma. Therefore, although tectono-thermal events younger than 370 Ma are recognized as being relatively pervasive in the southwest Meguma Terrane, both within plutonic rocks and the enveloping country rock, they remain undetected in the eastern part of the batholith and the surrounding Meguma Group metasedimentary rocks.

Conclusions

Results of Rb–Sr and $^{40}Ar/^{39}Ar$ dating of the East Kemptville topaz–muscovite leucogranite reveal a complex chronological history involving the superimposition of several tectono-thermal events that postdate initial intrusion and crystallization. Although the present study has not unequivocally determined the age of intrusion based on the radiometric techniques used herein, it has provided important insight into the conflicting results of previous Rb–Sr and $^{40}Ar/^{39}Ar$ studies.

Recently obtained Pb isotopic data (A. K. Chatterjee, personal communication, 1990) indicate a 368 Ma age for intrusion, crystallization and attendant mineralization at East Kemptville. Thus, earlier estimates of ca. 300 Ma for mineralization (Zentilli and Reynolds 1985) and 337 Ma for intrusion and crystallization, (Richardson *et al.* 1988) must be reinterpreted. These 300 and 337 Ma ages reflect resetting events that are further corroborated by the present study. The Rb–Sr whole-rock date of Richardson *et al.* (1988), obtained on quartz–topaz greisen, is verified here by a 344 ± 5 Ma Rb–Sr whole-rock ($n = 11$) date for the leucogranite and a 338 ± 2 Ma apparent plateau age ($^{40}Ar/^{39}Ar$) for muscovite from a leucogranite sample. These dates mark the time of final closure of Sr and Ar diffusion within the leucogranite (whole-rock scale) and muscovite, respectively, and are considered to reflect a pervasive tectono-thermal event, recorded by the presence of deformational textures in the leucogranite. Variable Rb–Sr ages obtained for muscovite – whole-rock (361–311 Ma) and feldspar – whole rock (276–240 Ma) indicate internal mobility of Sr and (or) Rb occurred on a whole-rock scale over a protracted period of time. The progressively younger ages recorded for Rb–Sr whole rock, $^{40}Ar/^{39}Ar$ muscovite, and Rb–Sr (muscovite – feldspar – whole rock) would be consistent with a single, long-lived tectono-thermal disturbance. However, an alternative interpretation whereby several episodic events occurred cannot at present be ruled out,

especially since the Wedgeport Pluton of 315 Ma age represents a later, discrete magmatic event.

The dates obtained at East Kemptville are coincident with other Rb–Sr and $^{40}Ar/^{39}Ar$ dates in the southwestern Meguma Terrane, thus indicating the regional significance of this study. A review of previously published radiometric data indicates that the tectono-thermal disturbances documented have a regional extent throughout the southwestern Meguma Terrane. In particular we cite (*i*) the 330 ± 7 Ma Rb–Sr whole-rock isochron age and ca. 260 Ma Rb–Sr whole rock – biotite ages for the Davis Lake pluton (Richardson *et al.* 1987, 1989), (*ii*) the ca. 315 Ma age for the Wedgeport Pluton (Cormier *et al.* 1988), (*iii*) the numerous $^{40}Ar/^{39}Ar$ ages obtained throughout the southern Meguma Terrane, summarized in Fig. 8, and (*iv*) the young Rb–Sr whole-rock ages obtained at Long Lake (332 ± 10 Ma) and Westfield (270 ± 134 Ma) by O'Reilly *et al.* (1985).

This study indicates the value of analyzing mineral separates as a routine procedure in Rb–Sr whole-rock studies in order to confirm whether the system has retained equilibrium since initial crystallization. A single analysis of one of the major silicate phases (i.e., mica, feldspar) can confirm whether later disturbances may have modified the Rb–Sr systematics.

Acknowledgments

Funds for this project were provided by the Canada – Nova Scotia Mineral Development Agreement 1984–1989, and the paper is published with permission of the Assistant Deputy Minister of the Mines and Minerals Branch, Nova Scotia Department of Mines and Energy. D. Kontak sincerely acknowledges the valuable support and input from colleagues working on the South Mountain Batholith project, namely M. A. MacDonald, R. J. Horne, M. C. Corey, L. J. Ham, and G. A. O'Reilly. Discussions with Dr. A. K. Chatterjee concerning his recent Pb-isotope investigation have been particularly beneficial and we acknowledge his permission to quote the data. Dr. P. H. Reynolds is thanked for providing the $^{40}Ar/^{39}Ar$ age spectrum and comments on the manuscript. Thanks are extended to Department of Mines and Energy personnel for assistance with manuscript preparation. Critical review of the manuscript by journal reviewers led to substantial improvements and their efforts are greatly appreciated.

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